

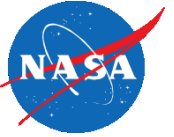


Developing a General Framework for Human Autonomy Teaming

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Summer L. Brandt
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April 18, 2017

Problems with Automation



- Brittle
 - Automation often operates well for a range of situations but requires human intervention to handle boundary conditions (Woods & Cook, 2006)
- Opaque
 - Automation interfaces often do not facilitate understanding or tracking of the system (Lyons, 2013)
- Miscalibrated Trust
 - Disuse and misuse of automation have lead to real-world mishaps and tragedies (Lee & See, 2004; Lyons & Stokes, 2012)
- Out-of-the-Loop Loss of Situation Awareness
 - Trade-off: automation helps manual performance and workload but recovering from automation failure is often worse (Endsley, 2016; Onnasch, Wickens, Li, Manzey, 2014)

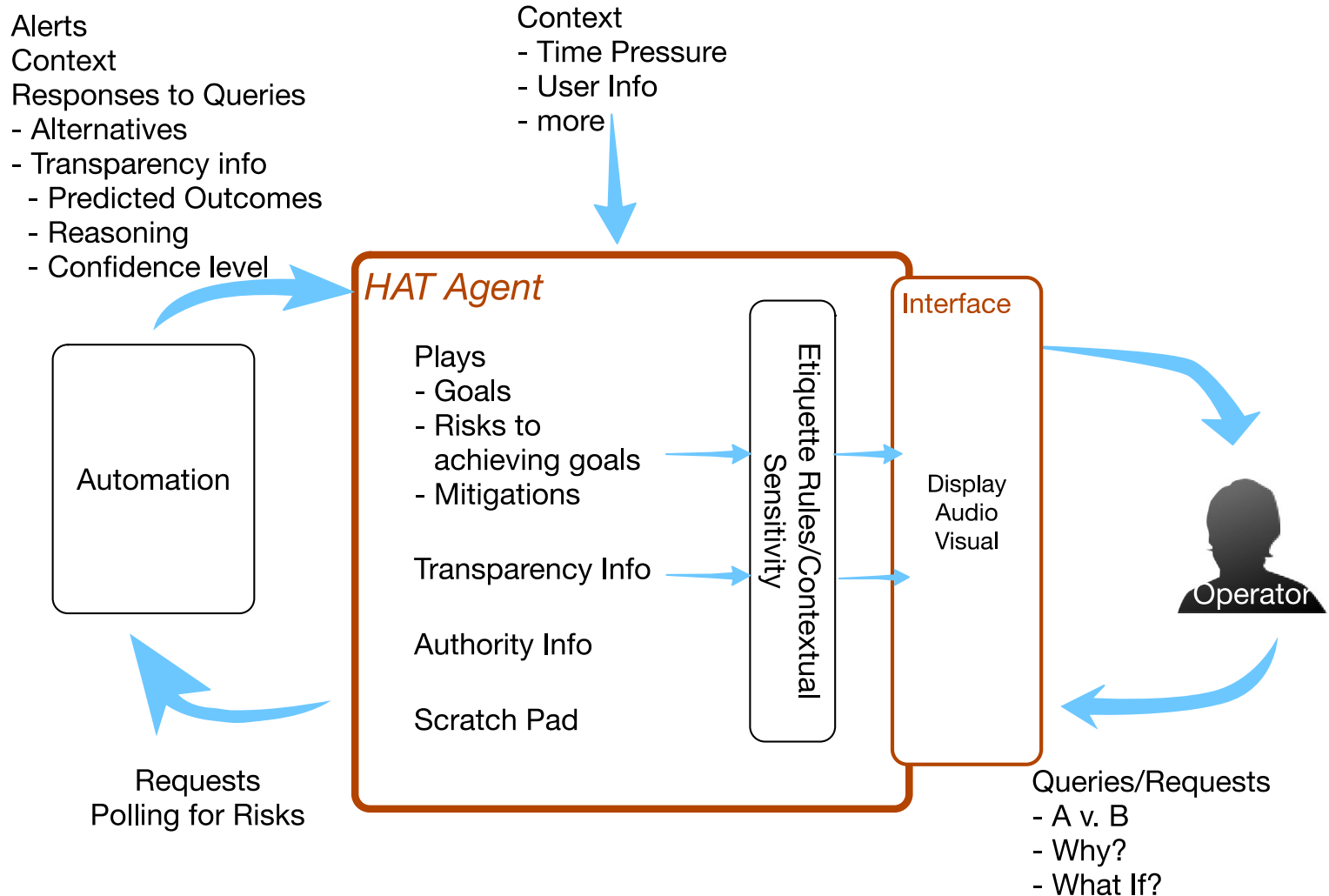
Tenets of Human Autonomy Teaming (HAT)

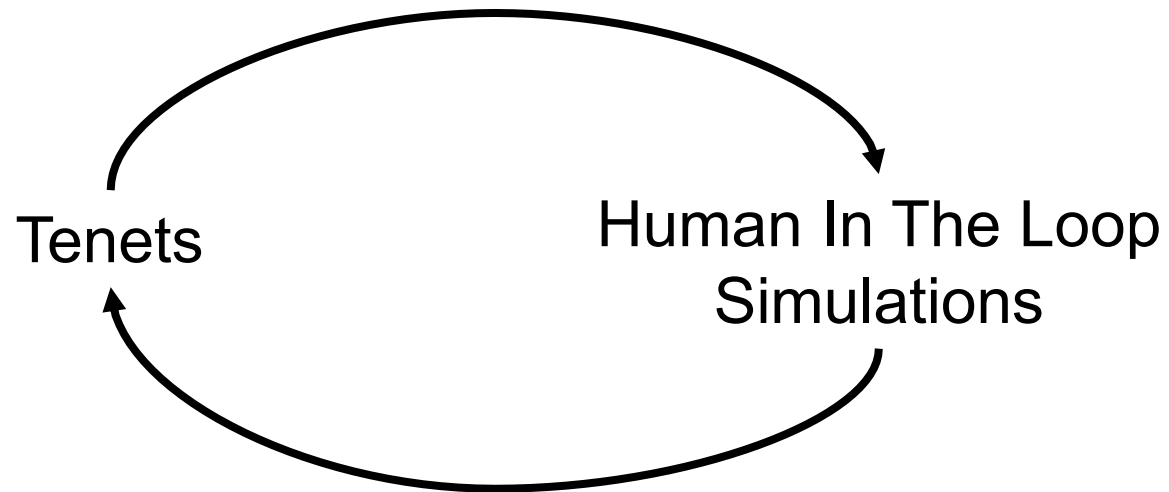


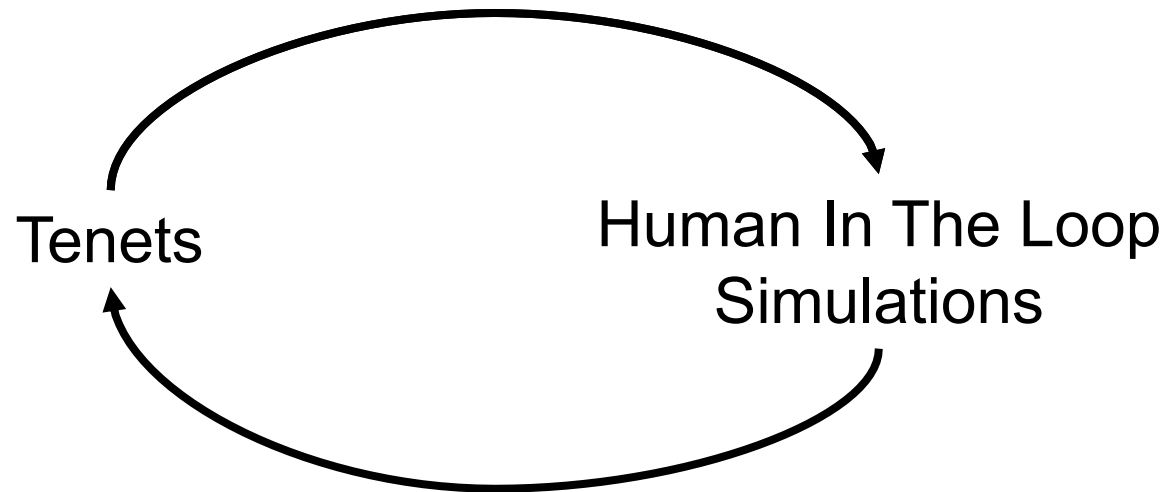
Make the Automation into a Teammate

Plays	Transparency	Bi-Directional Communication
	Communication of Rationale	
	Communication of Confidence	
	Shared Language	
	Shared Goals	
	Shared Plans	
	Agreed allocation of responsibility	
	Minimized Intent Inferencing	

HAT Agent







Simulated Ground Station



ELP and ACFP



Research prototype software, Intelligent Systems Division, PI: D. Smith

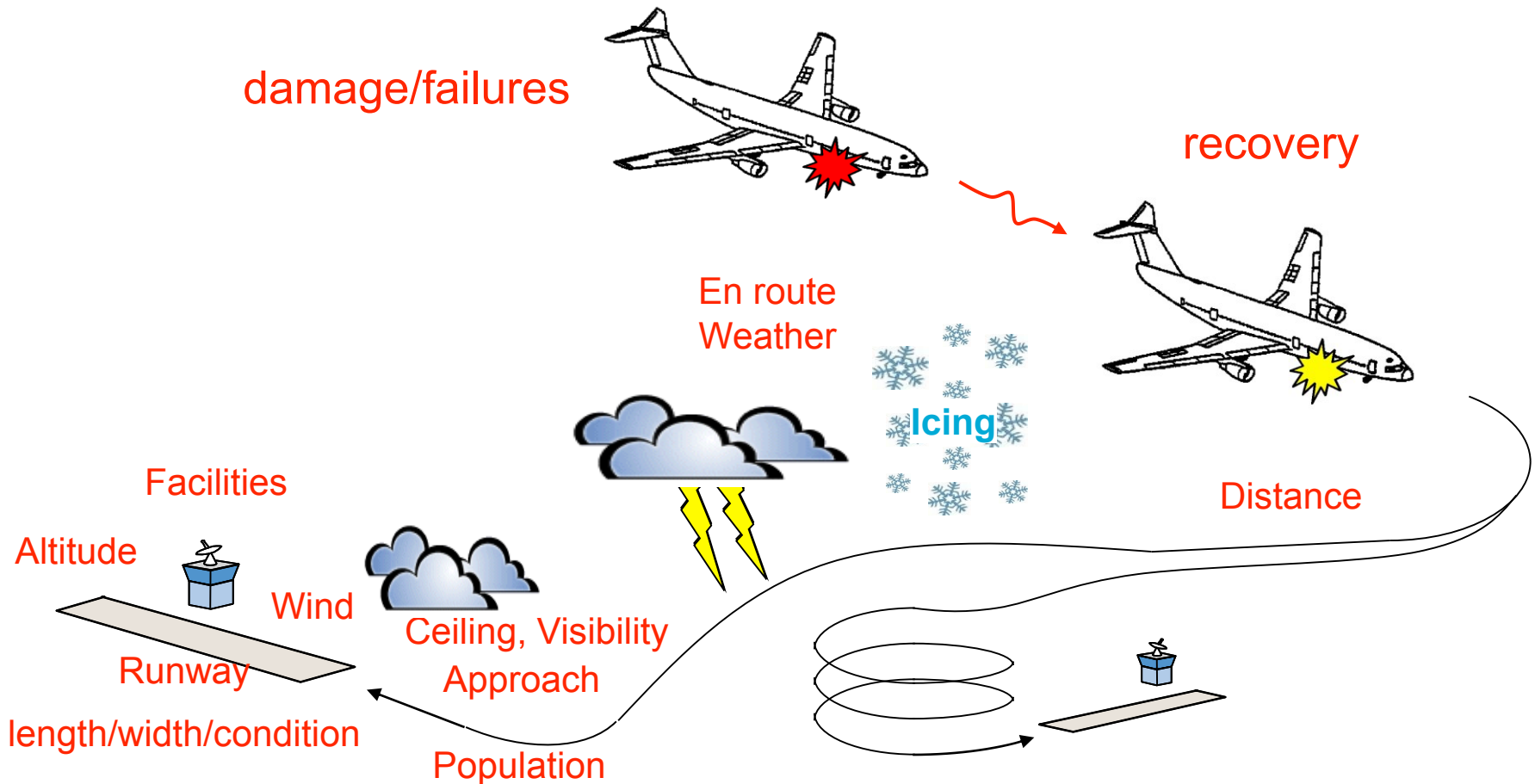
ELP – Emergency Landing Planner (2007-2012)

- Cockpit decision aid
- Route planning for (serious) emergencies
 - control system failures
 - physical damage
 - fires
- Time & Safety were dominant considerations

ACFP – Autonomous Constrained Flight Planer (2013-2017)

- Ground station decision aid
- Diversion selection, route planning, route evaluation
 - weather diversion
 - medical emergencies
 - less critical system failures

ELP Objective



**Find the best landing sites and routes
for the aircraft**

ELP Approach



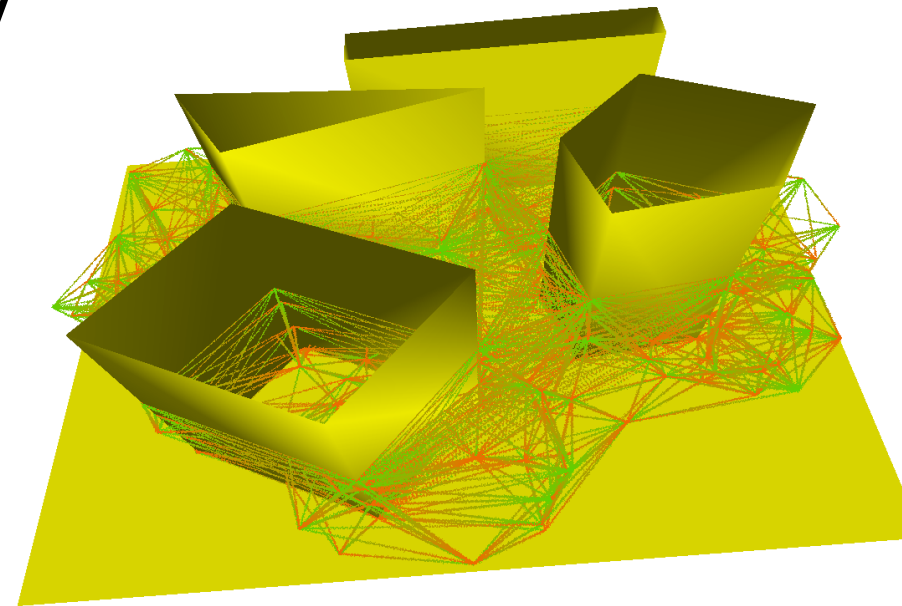
Consider all runways within range (150 miles)

Construct “obstacles” for weather & terrain

Search for paths to each runway

Evaluate **risk** of each path

Present ordered list



< 10 seconds

ELP's Risk Model



Enroute path

Distance/time

Weather

Approach path

Ceiling & Visibility

Approach minimums

Population density

Runway

Length

Width

Surface condition

Relative wind

Airport

Density altitude

Tower

Weather reporting

Emergency facilities

$P_{stable} \equiv$ probability of success / nm in stable flight

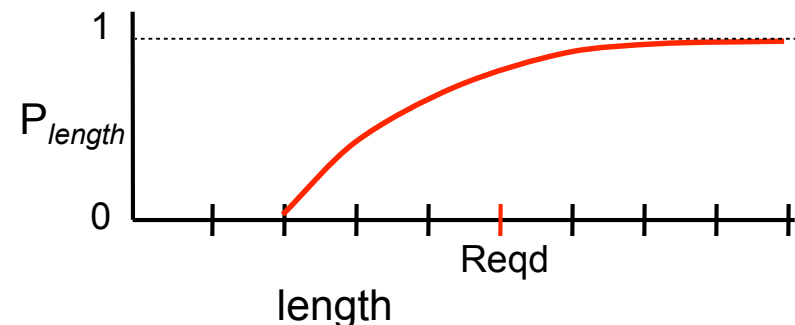
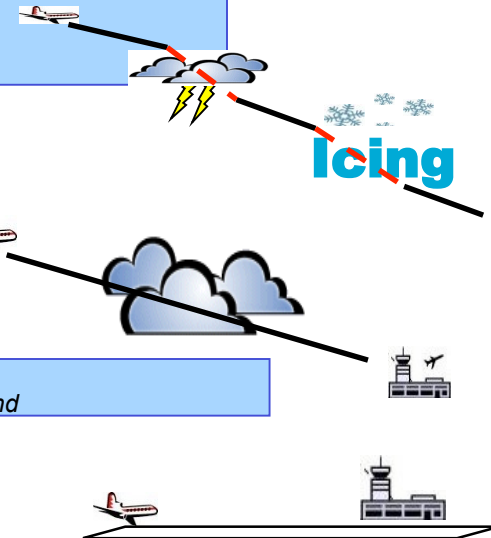
$P_{wx} \equiv$ probability of success / nm in light weather

$P_{leg} \equiv (P_{stable} * (P_{wx})^S)^D$

$P_{route} \equiv \prod P_{leg}$

$P_{appr} \equiv P_{leg} * P_{ceil} * P_{vis}$

$P_{rnwy} \equiv P_{length} * P_{width} * P_{surf} * P_{speed} * P_{xwind}$





Emergency Page on the CDU

Runway length

Runway

Airport

Select

Principal Risks

Page #

Distance to airport

Bearing to airport

Show Airport Info Page

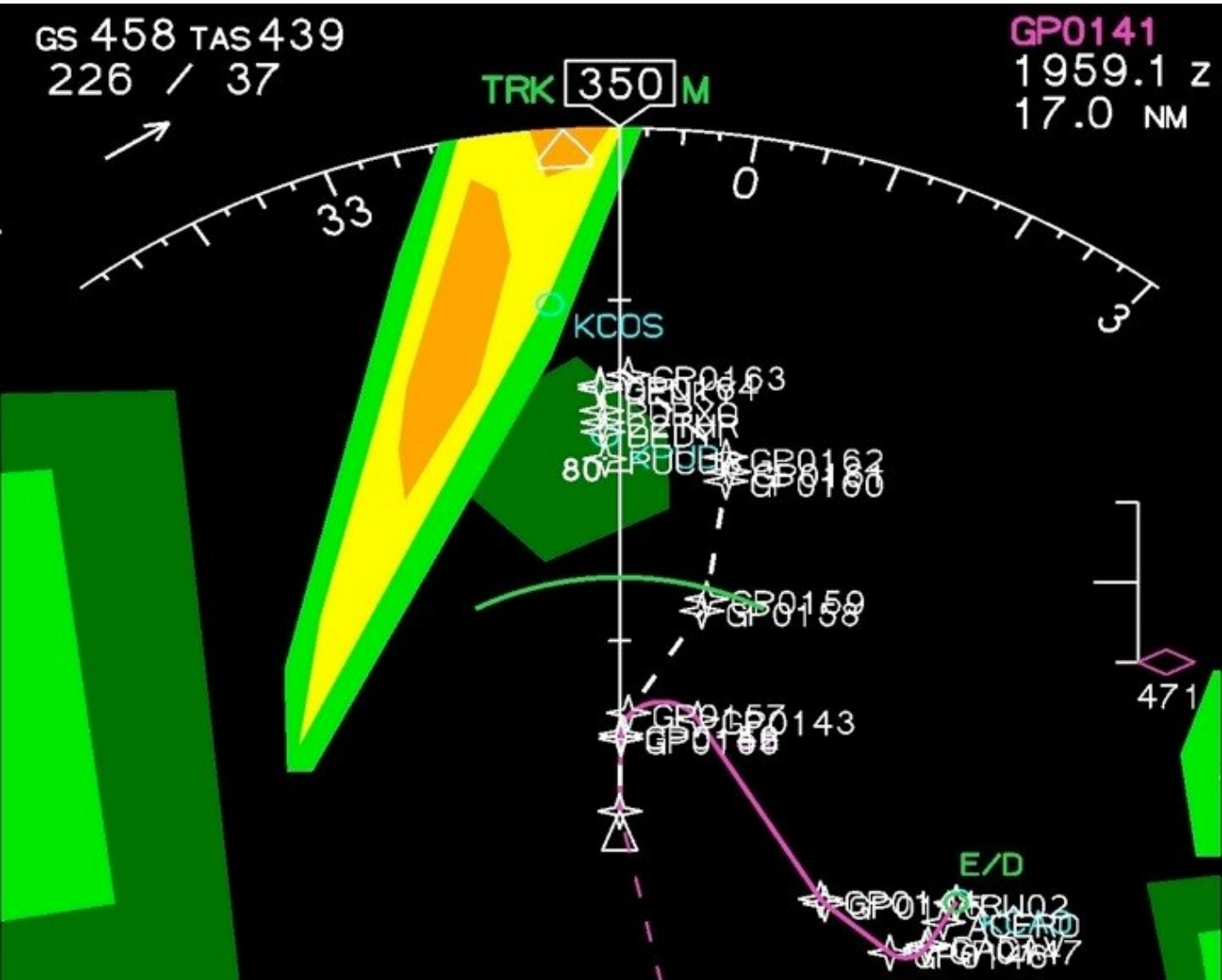
Update

Execute the selection

Go to Previous/Next Page



ELP Routes on the Navigation Display



ELP Experiment (2010)



Evaluation of ELP in ACFS

- 3 physical damage scenarios
- 5 pilot teams
- 16 scenarios each

Results

- Decision **quality** somewhat better in adverse weather
- Decision **speed** much better in adverse weather
- Damage Severity not a significant factor



Pilot feedback:

“ ... your software program alleviates the uncertainty about finding a suitable landing site and also reduces workload so the crew can concentrate on "flying" the aircraft.”

[The Emergency Landing Planner Experiment](#)

Nicolas Meuleau, Christian Neukom, Christian Plaunt, David Smith & Tristan Smith

ICAPS-11 Scheduling and Planning Applications Workshop (SPARK), pages 60-67, Freiburg, Germany, June 2011

ACFP differences



Multiple aircraft

Much wider geographic area

Additional optimization criteria

- medical facilities
- maintenance facilities
- passenger facilities
- connections

Constrained requests

- runway length
- distance

Route evaluation

- current route/destination
- proposed changes

RCO Ground station



Optimization

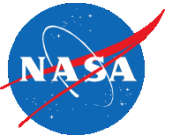


Situations:

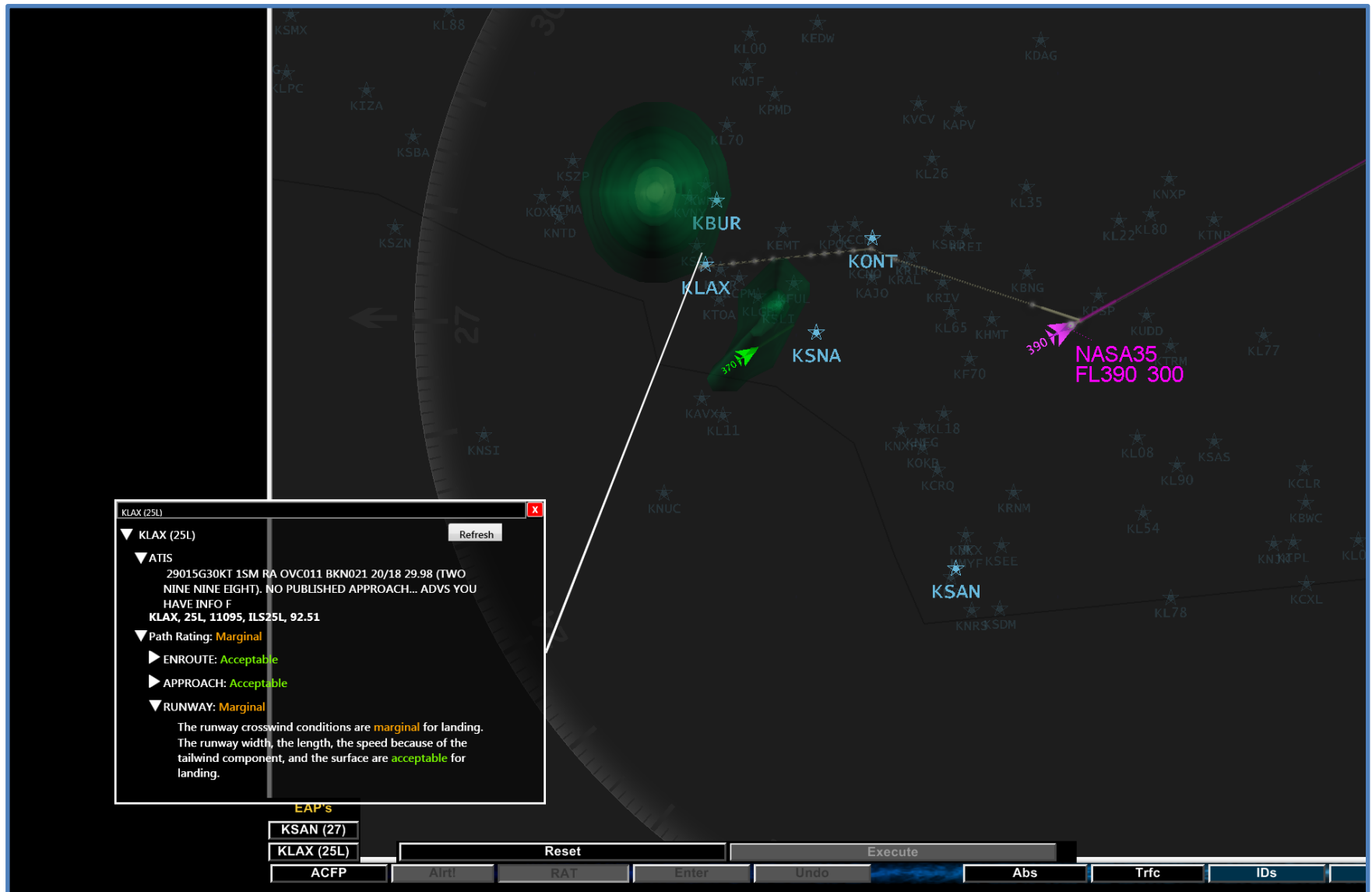
- weather reroute
- weather diversion
- systems diversion
 - anti-skid braking
 - radar altimeter
- medical emergency
 - heart attack
 - laceration
- engine loss
- depressurization
- damage
- cabin fire

Safety	Time	Medical	Conven.	Maint.
★	★		★	
★			★	
★			★	★
★			★	★
★		★	★	
★		★	★	
★	★		★	★
★	★			★
★	★			
★	★			

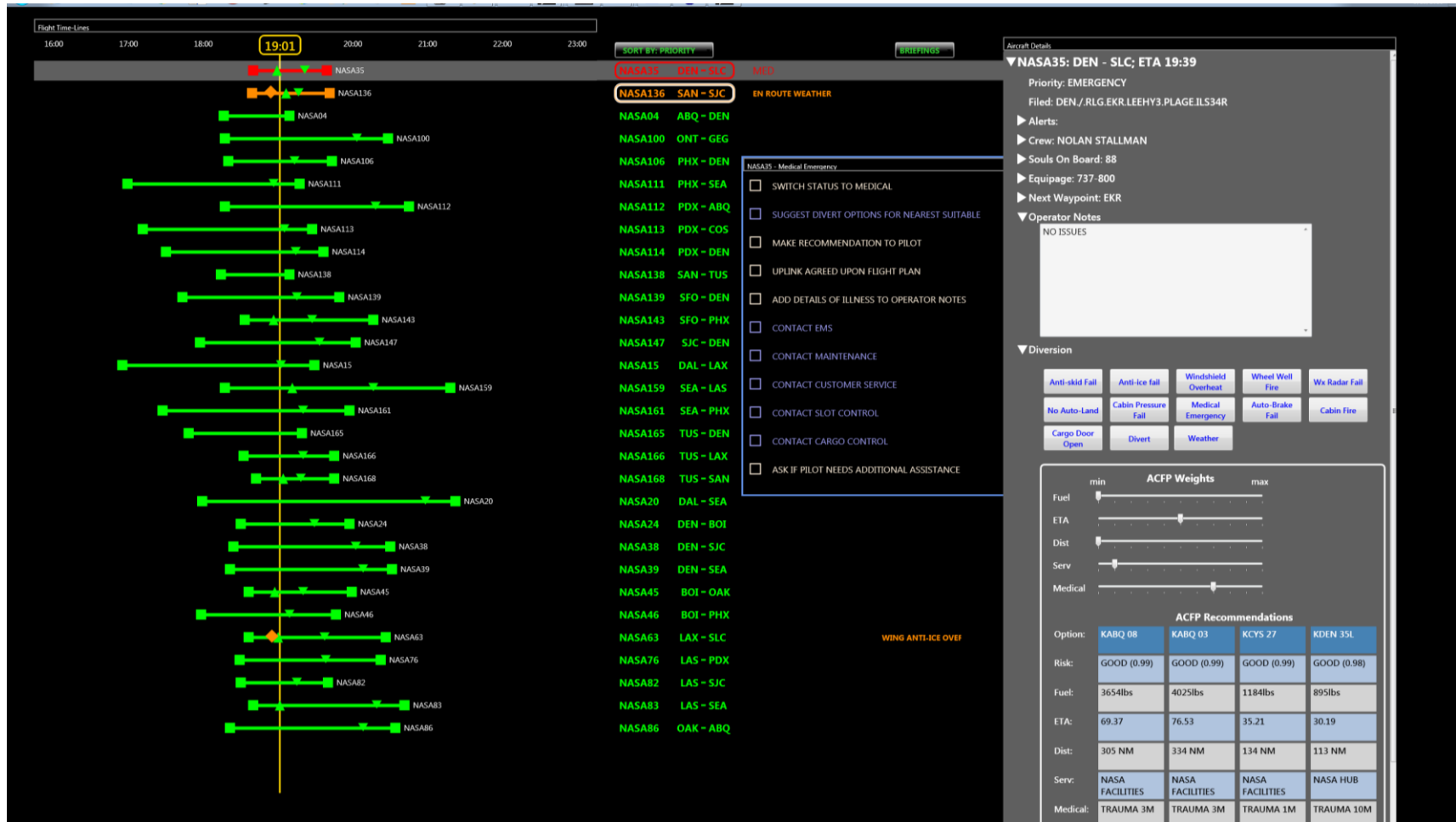
Simulated Ground Station



Implementing HAT Tenets in the Ground Station



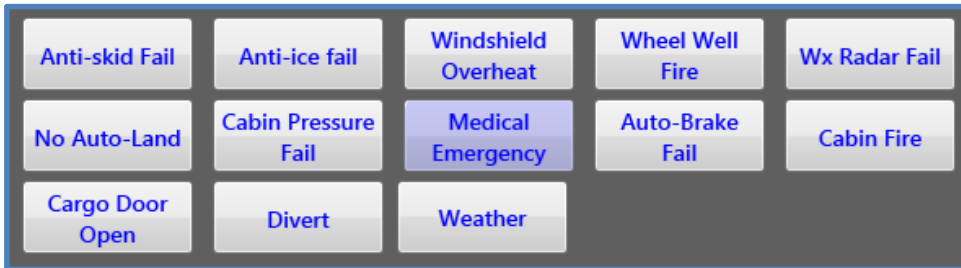
Implementing HAT Tenets in the Ground Station



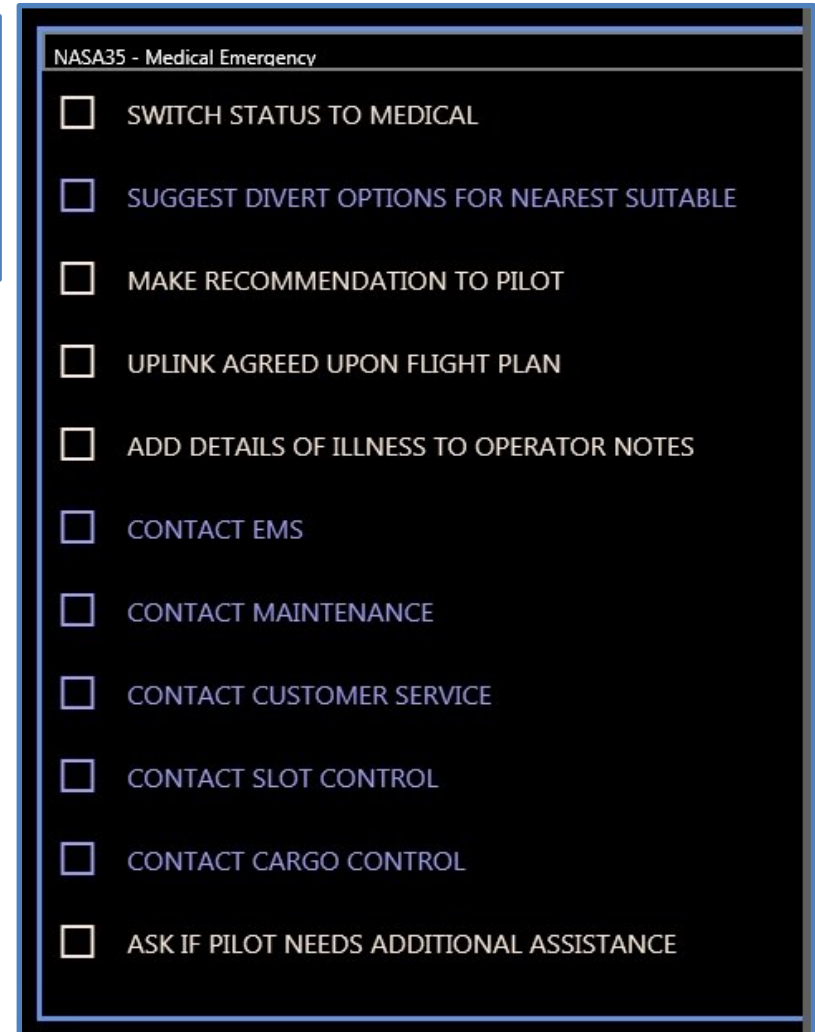


Implementing HAT Tenets in the Ground Station

- Human-Directed: Operator calls “Plays” to determine who does what



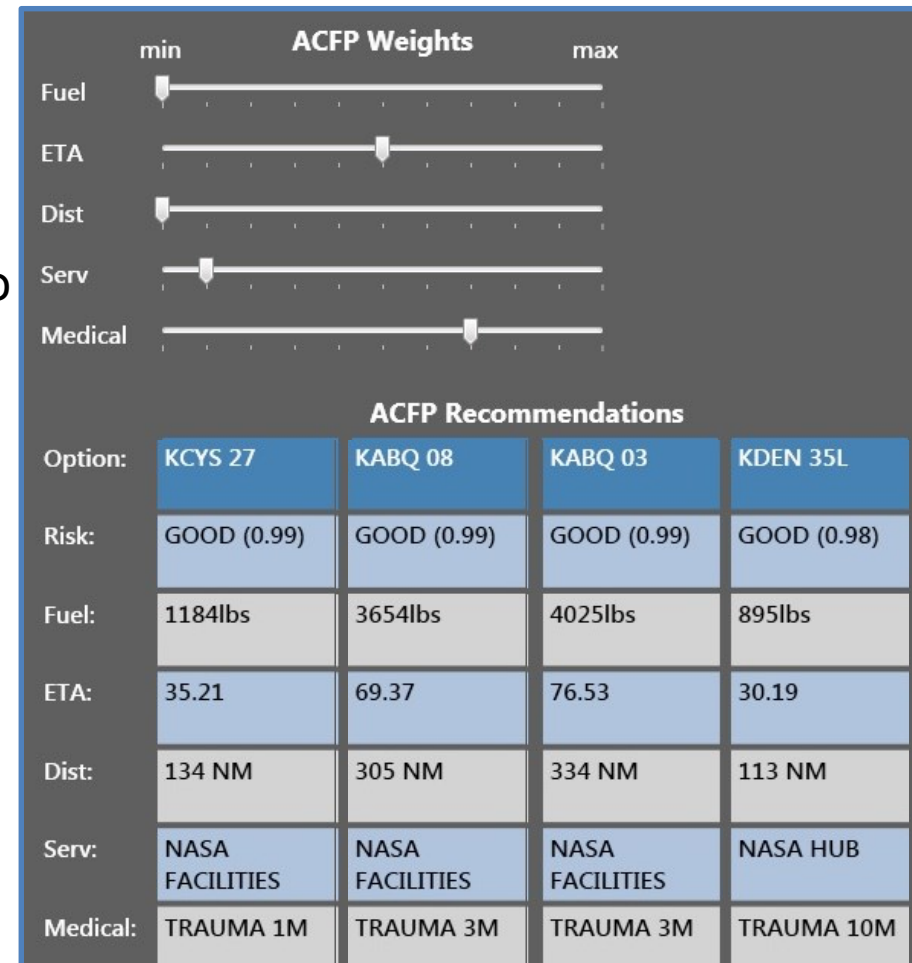
A play encapsulates a plan for achieving a goal.
It includes roles and responsibilities
 what is the automation going to do
 what is the operator going to do



Implementing HAT Tenets in the Ground Station



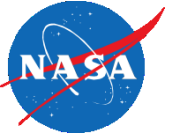
- Transparency: Divert reasoning and factor weights are displayed.
- Bi-Directional Communication: Operators can change factor weights to match their priorities. They can also select alternate airports to be analyzed
- Shared Language/Communication: Numeric output from ACFP was found to be misleading by pilots. Display now uses English categorical descriptions.





HAT Simulation: Tasks

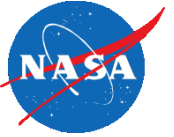
- Participants, with the help of automation, monitored 30 aircraft
 - Alerted pilots when
 - Aircraft was off path or pilot failed to comply with clearances
 - Significant weather events affect aircraft trajectory
 - Pilot failed to act on EICAS alerts
 - Rerouted aircraft when
 - Weather impacted the route
 - System failures or medical events force diversions
- Ran with HAT tools and without HAT tools



HAT Simulation: Results

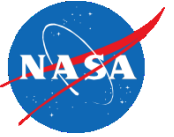
- Participants preferred the HAT condition overall (rated 8.5 out of 9).
- HAT displays and automation preferred for keeping up with operationally important issues (rated 8.67 out of 9)
- HAT displays and automation provided enough situational awareness to complete the task (rated 8.67 out of 9)
- HAT displays and automation reduced the workload relative to no HAT (rated 8.33 out of 9)

HAT Simulation: Debrief



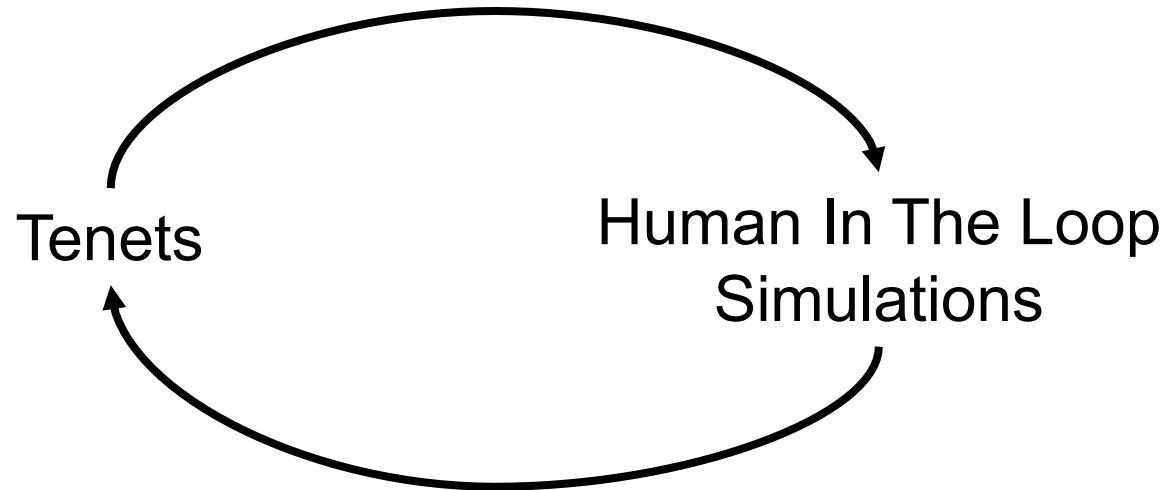
- Transparency
 - “This [the recommendations table] is wonderful.... You would not find a dispatcher who would just be comfortable with making a decision without knowing why.”
- Negotiation
 - “The sliders was [sic] awesome, especially because you can customize the route.... I am able to see what the difference was between my decision and [the computer’s decision].”
- Human-Directed Plays/Shared Plans
 - “Sometimes [without HAT] I even took my own decisions and forgot to look at the [paper checklist] because I was very busy, but that didn’t happen when I had the HAT.”

HAT Simulation: Summary

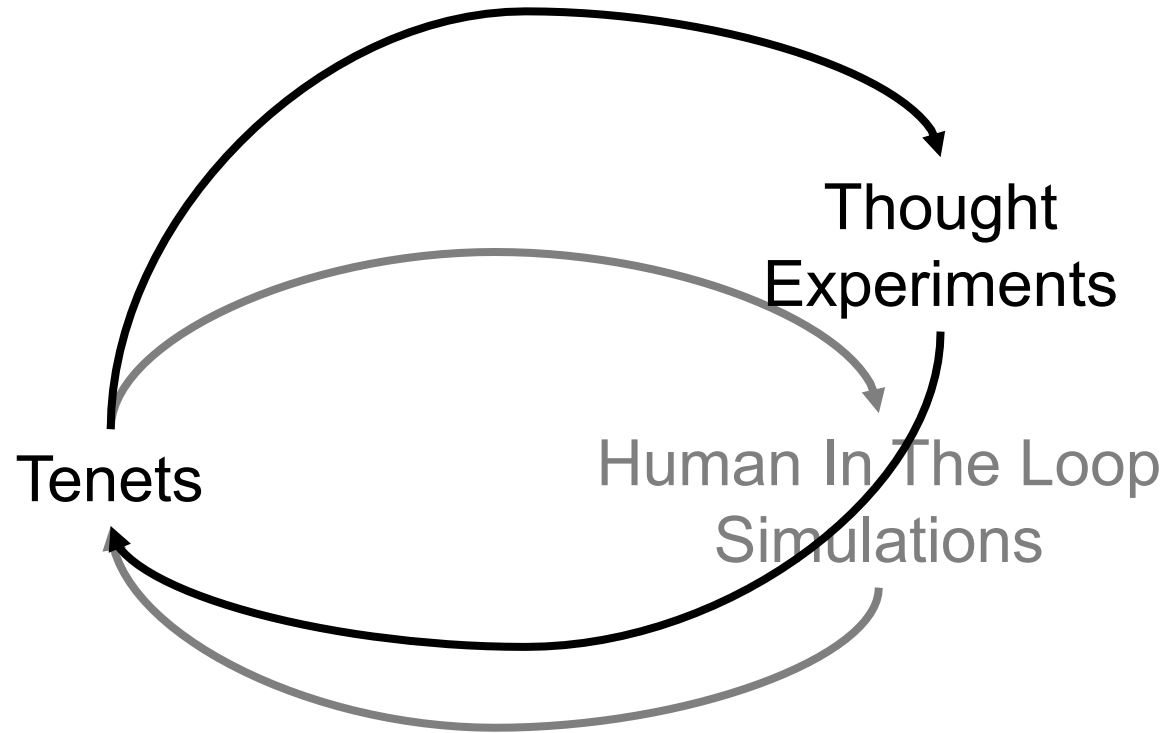
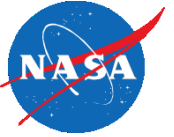


- Participants liked where we were headed with the HAT concept
 - Increased Situation Awareness
 - Reduced Workload
- Things we didn't get quite right
 - Annunciations: People liked them but thought there were too many
 - Voice Control: Did not work well. Need a more complete grammar, better recognition
 - Participants didn't always understand what the goal of a play was
- Things we didn't get to
 - Airlines hate divers. We need to put in support to help avoid them
 - Plays need more structure (branching logic)
 - Roles and responsibilities need to be more flexible
 - Limited ability to suggest alternatives

Summer '17



Generalization



HAT in Photography



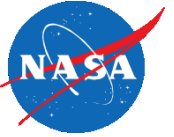
HAT in Photography



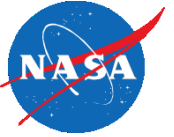
HAT in Photography



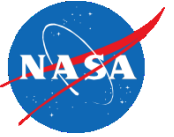
HAT in Photography



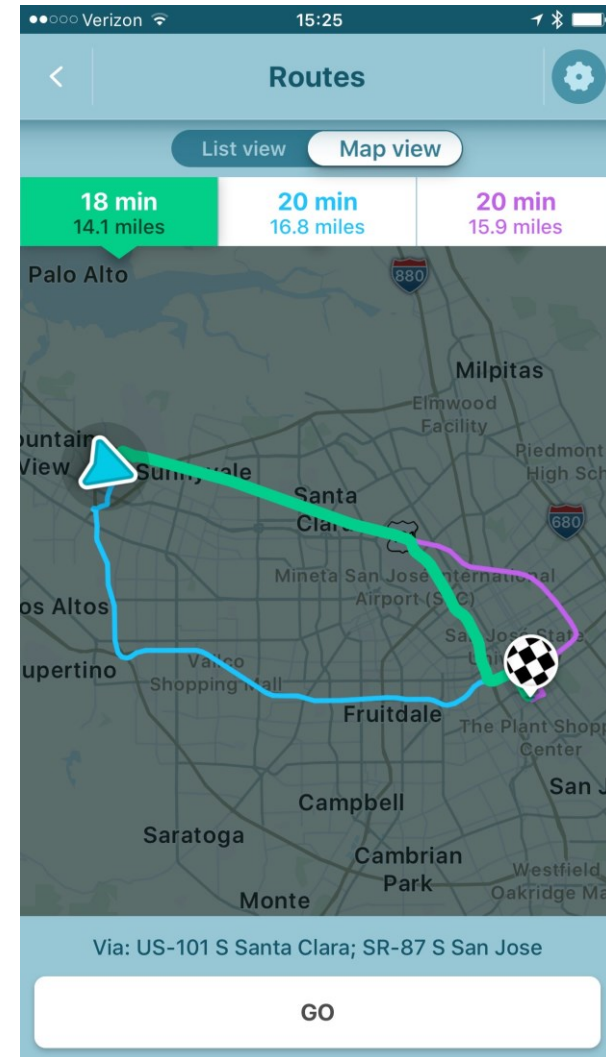
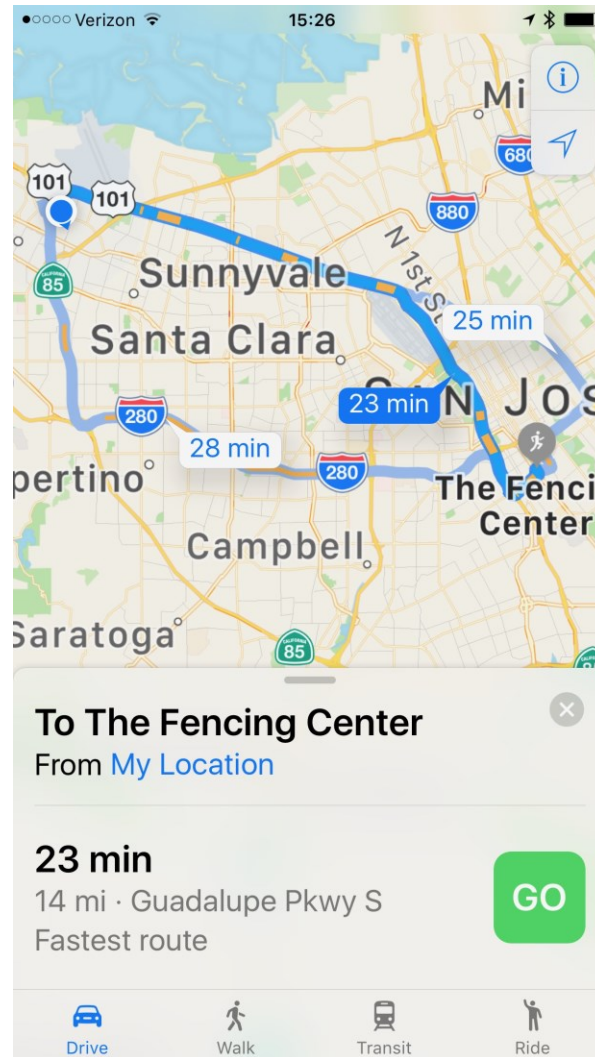
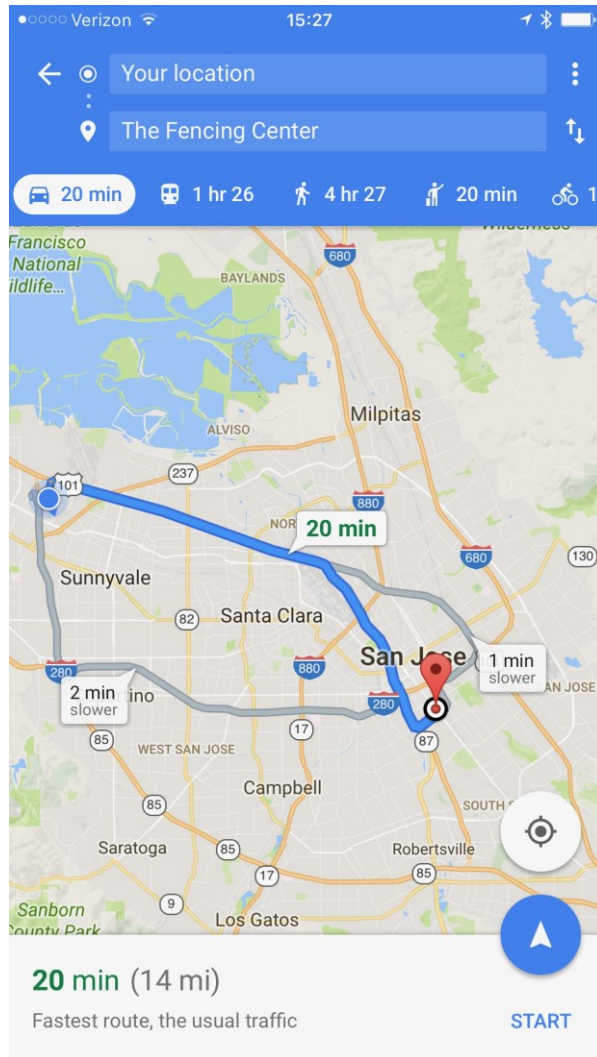
HAT in Photography



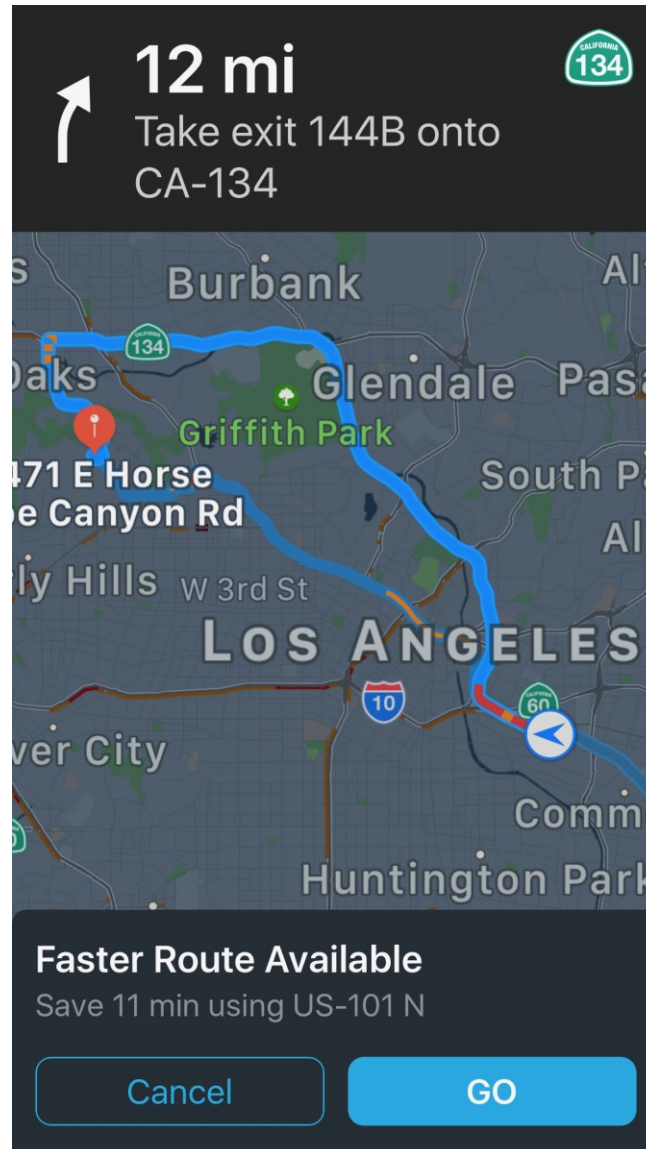
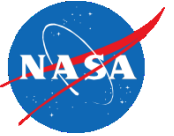
HAT in Photography



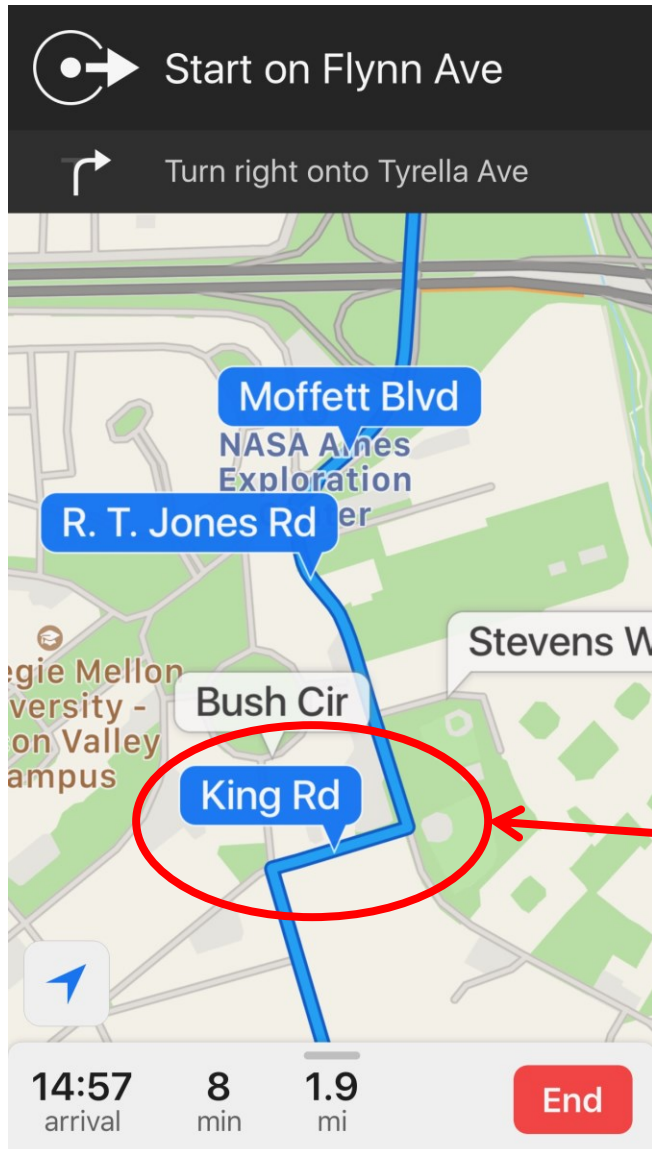
HAT in Navigation



HAT in Navigation



HAT in Navigation



Centerwide Announcement

UPDATE - Main Gate Reopening Monday, April 4, 2016

To: Recipient List Suppressed

TO: Resident Staff

FROM: Janice Fried, Director, NASA Research Park Office

SUBJECT: UPDATE - Main Gate Reopening Monday, April 4, 2016

The Main Gate to NASA Ames Research Center will reopen ** at 6

You will notice that the Main Gate intersection has changed. The g
need to present identification at the Arnold Avenue gate. Because
badges at the visitor badging office before approaching the Arnold

All gates will return to the same operating hours as before the clos

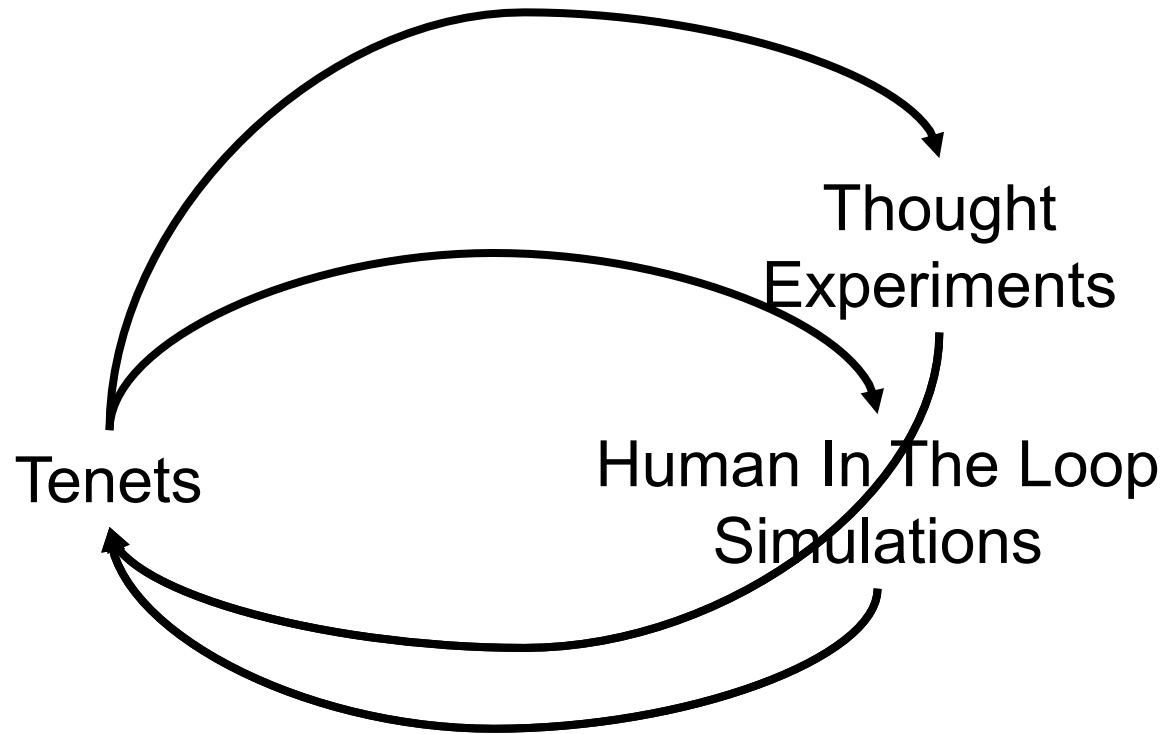
- The Moffett Blvd./Main gate and Arnold Avenue gate will be oper
- The Ellis Street gate will operate seven days a week, from 5 a.m
- The Mark Avenue gate will operate from Monday through Friday,
- The King Road/Gate 18 will be closed.

Construction will continue in the area of the Main gate. There may
during this period of construction. Please allow additional travel tin
advance of known delays.

Lessons



- Seems applicable to a wide variety of automation
- Plays are a big part of the picture
 - Provide a method for moving negotiation to less time critical periods
 - Provide a mechanism for creating a shared language

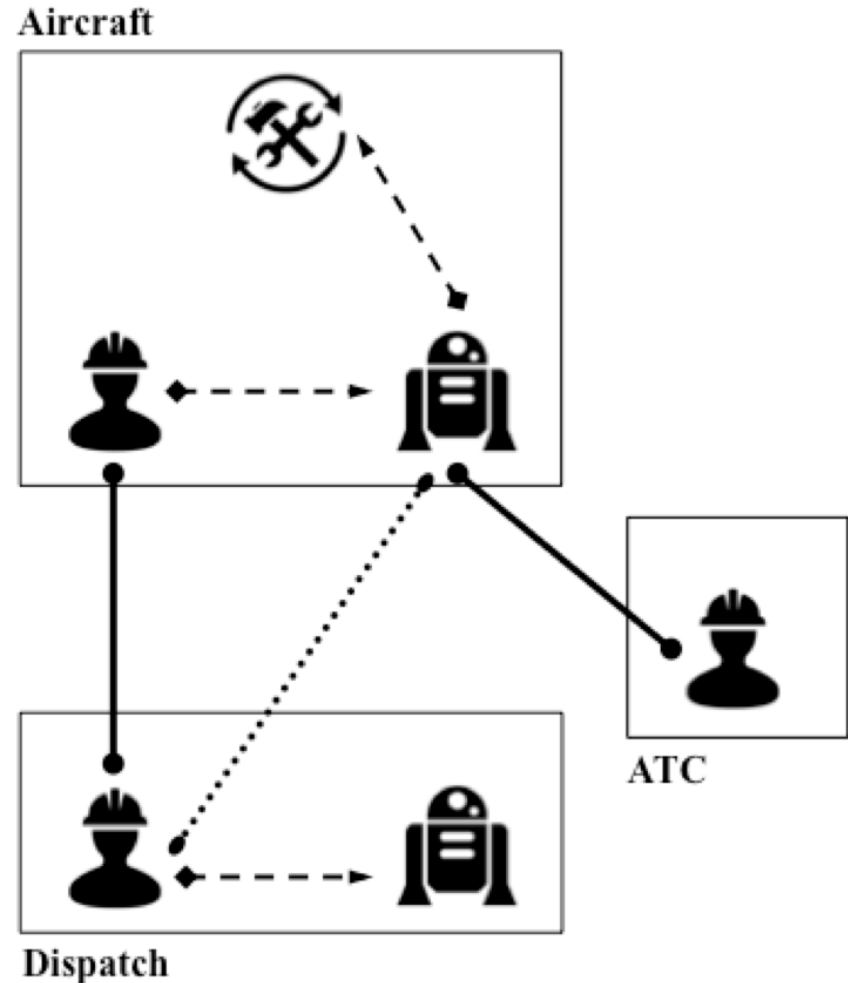




- Looking at a variety of situations, we see common problems with common solutions
 - Bi-Directional Communication solves a problem of keeping the human in the loop with potential problems in the current plan and reduces brittleness by opening up the system to operator generated solutions
 - Plays solve the problem allowing the system to adopt to different conditions without having the system infer the operator's intent
- In other domains, people have attempted to capture similar problem-solution pairs using “design patterns”
 - Architecture and Urban Planning (Alexander, et al., 1977)
 - E.g., Raised Walkways solve the problem of making pedestrians feel comfortable around cars
 - Computer Programming (Gamma, et al., 1994)
 - E.g., Observers solve the problem of maintaining keeping one object aware of the state of another object

Design Patterns for HAT

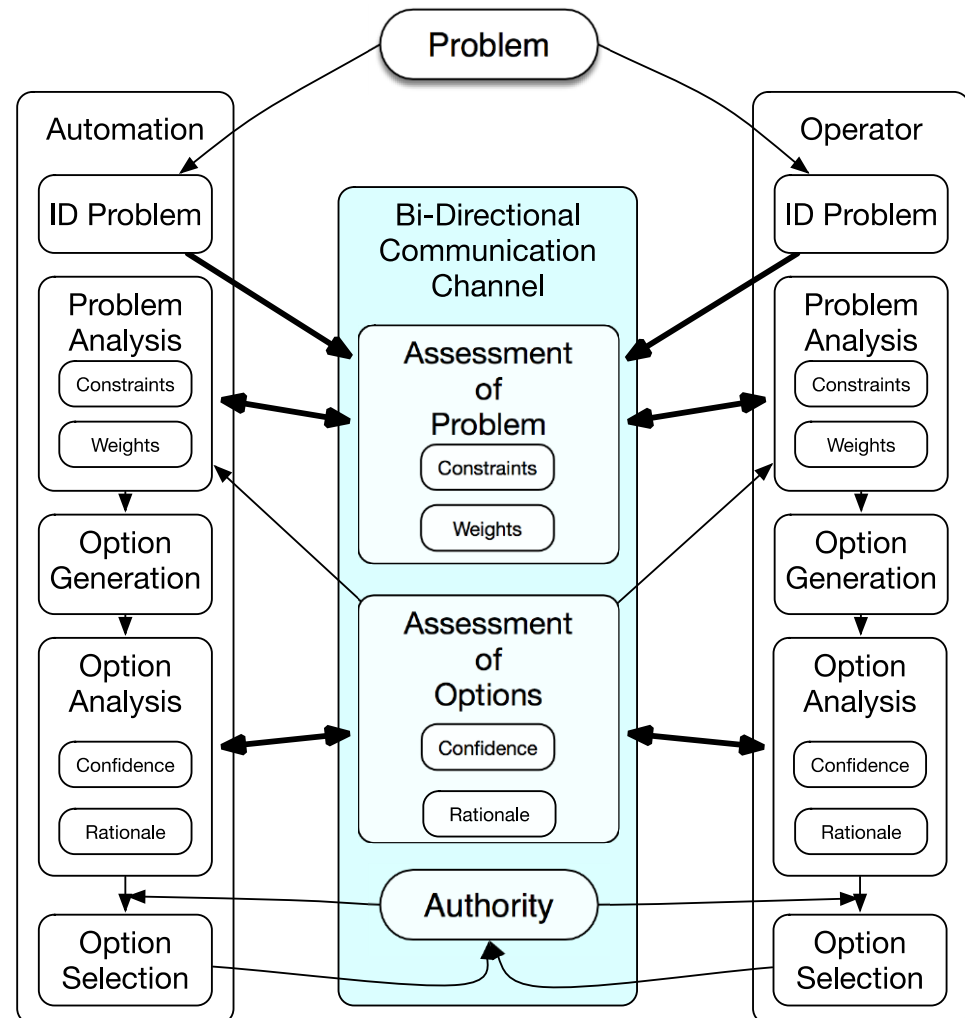
- Working with the NATO working group on Human Autonomy Teaming (HFM-247) to develop design patterns for HAT
- Original Conception was to identify relationships between different agents (after Axel Schulte, Donath, & Lange, 2016)



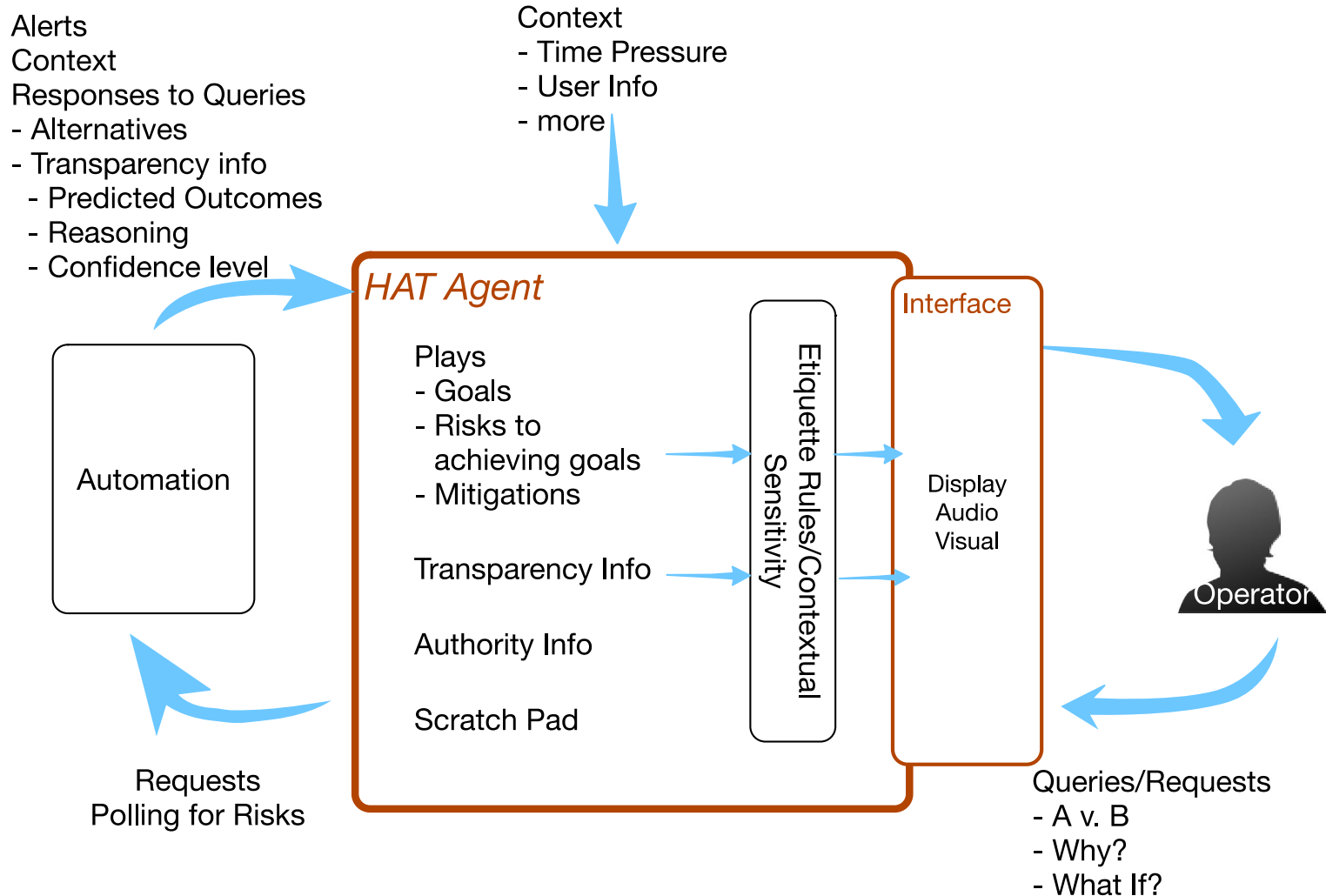
Design Patterns for HAT

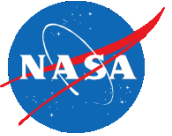


- Working with Gilles Coppin from the NATO Working Group on a Bi-Directional Communication pattern
- Modeled after Gamma et al specifications:
 - Intent: Support generation of input from all relevant parties and its integration into decisions
 - Motivation: Reduce brittleness of the system by consolidating information and skills
 - Applicability: May not be applicable in urgent situations or with automation that lacks structure (e.g., neural networks)



HAT Agent





Thank you!

Three papers to appear in the proceedings of at the 8th International Conference on Applied Human Factors and Ergonomics (AHFE 2017).

- Shively, R. J., Lachter, J., Brandt, S. L., Matessa, M., Battiste, V., & Johnson, W. W., Why Human-Autonomy Teaming?
- Brandt, S.L., Lachter, J., Russell, R., & Shively, R. J., A Human-Autonomy Teaming Approach for a Flight-Following Task.
- Lachter, J., Brandt, S. L., Sadler, G., & Shively, R. J., Beyond Point Design: General Pattern to Specific Implementations.

Papers on ELP:

- Meuleau, N., Plaunt, C., Smith, D., Smith, T., An Emergency Landing Planner for Damaged Aircraft. Twenty-First Conference on Innovative Applications of Artificial Intelligence (IAAI-09), pg 114-121.
- Meuleau, N., Plaunt, C., Smith, D., Smith, T., The Emergency Landing Planner Experiment. ICAPS-11 Scheduling and Planning Applications Workshop (SPARK) pg 60-67.